EXHIBIT G

FINAL PRESCRIPTIONS

11.1 GUIDELINES FOR IMPLEMENTING MASS WASTING PRESCRIPTIONS

Hazards to Private Resources

The Acme Watershed Administrative Unit (WAU) contains many private residences and structures. Some of these private structures are located on naturally hazardous landforms, including debris flow fans, alluvial fans, stream terraces and on areas directly below steep hillslopes prone to failure. Some, but not all, of these naturally hazardous landforms have been identified and mapped by Whatcom County Planning Department (1992). This watershed analysis does not attempt to map all of the hillslope and fan hazard areas in greater detail. Nor does it attempt to map hazard areas in relation to private structures, since the number and location of such structures occurring on naturally hazardous areas will change over time. Therefore, we recommend that potentially hazardous land forms, such as debris flow and alluvial fans, streamside areas and areas below steep hillslopes, be identified during preparation for specific forest practice activities, although the Acme watershed analysis and the Whatcom County alluvial fan hazard maps can be used as general guides.

Impacts to private property, as opposed to public resources, are not formally considered in watershed analysis (WFPB, 1994), which means that vulnerability of private property to identified hillslope hazards is not determined, and rule calls with respect to private property are not developed because they are not public resources. However, the team conducting the Acme watershed analysis considered impacts to private property and recommends that mass wasting prescriptions developed for high and moderate mass wasting map units be applied on a voluntary basis in those areas of the Acme WAU where there is an absence of fish-bearing channels but that contain private property vulnerable to mass wasting.

Map Resolution Issues

The slope stability assessment contained in watershed analysis is based on up-to-date scientific information on landsliding and the effects of forestry activities on landslide initiation, and therefore, forestry-related landsliding is expected to be substantially reduced when potentially-unstable landforms are identified in the field and prescriptions are followed. However, in some cases, areas of potential landslide hazard may not have been identified accurately during a watershed analysis (or any slope stability assessment) because of: 1) the dependence on remote-sensed data (i.e. aerial photographs); 2) the relatively short (40yr) and unique history of storms that triggered the landslides used to create the mass wasting map units (e.g. longer and different time periods and larger storms than what occurred during the aerial photo record may yield landslides in areas previously mapped as low landslide potential); and 3) the incomplete scientific understanding of all landslide mechanisms. For all of the above reasons, the mass wasting map units and hazard units developed during this watershed analysis may not completely identify all of the potentially unstable areas. In addition, because of the inherent difficulty in recognizing the exact combination of failure mechanisms at each site, the recommended prescriptions may not in every case reduce or eliminate forestry-related landsliding. Furthermore, naturally-occurring landsliding, that is not related in any way to forestry activities, can present a significant natural hazard to public (and private) resources, and these landslides cannot be predicted, nor at times can they be differentiated from landslides related to land use activities.

Implementation of prescriptions that apply to mass wasting hazards in the Acme WAU require the identification of mass wasting map unit (MWMU) boundaries in the field by the proponent. The identification and field verification of map unit boundaries shall be accomplished during preparation for forest practice activities by using the descriptions, based primarily on slope gradient, slope form, and evidence of past landslides which are listed in Table 3-2 of the mass wasting module. As part of the forest practice application, the applicant shall clearly identify the locations of ARS MW-1, ARS MW-2, and ARS MW-3 or state that none of the above were found in the proposed forest practice. A detailed forest practice preparation narrative shall accompany Forest practice applications that implement prescriptions applicable to mass wasting hazards. The narrative shall explain decisions made in cases where prescriptions offer flexibility, such as in the cases of wind throw prevention measures and bedrock hollow crossing structures.

Specialist Qualifications

To qualify as a **Geotechnical Specialist**, an individual shall have at least (i) either: (A) a Master's degree in geology or geomorphology or a related field or (B) a significant amount of post-graduate course or thesis work or other training in geomorphology or mass-movements; and (ii) an additional 5 years of field experience in the evaluation of relevant problems in forested lands.

To qualify as a **Forest Engineer** for the purposes of advising on road construction prescriptions, an individual should have a minimum of five years of appropriate field experience and either a bachelor of science degree in forest engineering or specialized education related to the location, design and construction of roads in mountainous terrain. For issues related to slope stability, a forest engineer must have specialized education or training related to slope stability in forest environments.

To qualify as a **Forester,** an individual must have a minimum of five years of applicable field experience and either a bachelor of science degree in forestry or an associates degree in forestry and have specialized education or training related to slope stability in forest environments.

11.2 CAUSAL MECHANISM AND PRESCRIPTION REPORTS

Acme WAU
Report #1

Resource Sensitivity: ARS MW-1

Input Variables:	Debris flow scour and deposition; channel aggradation; coarse and fine sediment (and woody debris)
Hazard:	Moderate or High
Vulnerability:	High (Fish habitat) High (Public Works)
Rule Call:	Prevent or avoid

Situation Statement:

Debris flows and dam-break floods from MWMU #1, and MWMU #10 have the potential to deliver large volumes of coarse and fine sediment to water and fish habitat in Channel Segments #5 and #6. Coarse sediment deposition could also impact public bridges and adjacent roadways (Bridges #7 through Bridge #13, and Bridge #17 on the Public Works map). Debris flow deposits could bury channel roughness elements (boulders, LWD) and fill pools. Loss of these channel obstructions could increase average water velocities, reduce new pool formation rates, and reduce localized storage of spawning gravels. Aggraded channels allow greater sub-surface flow, which would extend periods of dry channels during low flow seasons. Fine sediments (<0.85mm) have the potential to degrade rearing and spawning habitat in Channel Segments #1, #4, #5, and #6 by filling pools and reducing spawning gravel suitability. Suspended sediment can also affect fish when delivered in sufficient quantity and duration.

Map Unit Description and Process

Please refer to the Mass Wasting Assessment for more detailed description and discussion of these MWMUs.

MWMU #1 and MWMU #4 are convergent topography greater than or equal to 36 degrees (73%), and include bedrock hollows, channel heads, AND inner gorges (see landform definitions) of first-order channels. These map units are naturally prone to landsliding, and are the primary source of debris flows. To see field examples of bedrock hollows, refer to photographs in: *Slope Instability and Forest Land Management, A Primer and Field Guide*, 1997/1998, Benda, L., Veldhuisen, C., Miller, D., Miller, L., Earth Systems Institute, Seattle, WA, 84 pages (see Appendix).

MWMU #2 and MWMU #5 are inner gorges, greater than or equal to 40 degrees (84%) in Chuckanut Formation or greater than or equal to 36 degrees (73%) in phyllite terrain, along second-- and higher--order channels which contain all slope forms (convergent, divergent and planar). Landslides in these map units may trigger debris flows or dam-break floods.

MWMU #3 is generally non-convergent topography, greater than or equal to 31 degree (60%) hillslopes with primarily thin soils (3 to 6 feet). Bedrock hollows can occur here in various forms of development. The oldest features are deeply incised with sideslope gradients typically in excess of 45 to 50 degrees. In these cases, the drainage divide of a mature hollow may be 500 to 700 feet from the hollow axis (for photo examples of bedrock hollows, see Benda et al (1998)). Note that the actual drainage divide of a hollow is likely a subtle break in slope as the hollow slowly breaks into a planar or divergent surface. These strongly convergent and steep hollows are the most potentially unstable.

Hollows in earlier phases of development (i.e., younger) also exist in the Acme WAU and are characterized by more subtle convergence with slide slope gradients ranging from 30 to 40 degrees (the hollow axis may also be less steep). The drainage area of these hollows (also referred to as "wedges" by Buchanan (1998)) can be relatively small, and the drainage divide of small hollows may extend less than 100 to 200 feet away from the hollow axis. These sites are less potentially unstable since they should have a lower convergence of soil and groundwater. It is possible that small hollows that are filled with soil will be difficult to detect in the field. Likely locations of small hollows are at the heads of first-order or type 5 streams.

Although the relative stability is greater than MWMU #1, #2, #4 and #5, MWMU #3 also contains inclusions of convergent topography greater than or equal to 31 degrees (60%), including inclusions of MWMU #1.

MWMU #7 is an undifferentiated mixture of MWMUs #1, #2, #3, #4, and #5, as well as stable topography. MWMU #7 can also contain areas described by MWMU #6 (Devil's Slide), although the approximate perimeter of the Devil's Slide area is demarcated by MWMU #6 in Figure 3-3.

MWMU #10 is generally planar topography, 31 to, but not including, 36 degree hillslopes with primarily thick soils adjacent to inner gorges in phyllite terrain which contains all slope forms (convergent, divergent and planar). Although the relative stability is greater than MWMU #1 and MWMU #2, landslides in this map unit may trigger debris flows or dam-break floods. Landsliding mechanisms include shallow and small (<200 square feet) deep failures, including earthflows.

Landform Definitions

Some *signs of instability* that could be used to define MWMU #1, MWMU #2, MWMU #3, MWMU #4, MWMU #5 and MWMU #10 include:

i) existing landslides and old landslide scarps;
ii) discontinuity surfaces as described in the Mass Wasting Assessment pg 3-19 (Buchanan, P. 1988, Debris avalanche and debris torrent initiation, Whatcom County, Washington, U.S.A. MS thesis, Department of Geological Sciences, University of British Columbia);
iii) tension cracks*;
iv) scarp and bench topography indicating rotational slumps*;
v) tipped and jackstrawed trees*;
vi) springs and hydric vegetation.
(* more indicative of deep-seated failure sites, rather than shallow-rapid landslide sites)

A *channel head* is generally located in a convergent area, often at the base of one or more hollows, where subsurface flow emerges and a channel, defined by banks and substrate, begins.

A *high-hazard bedrock hollow* is defined as an unchanneled swale or valley with a slope gradient downhill along the axis of the hollow greater than or equal to 36 degrees (73%). Hollows may also contain the channel head; an area often characterized by springs and small landslide scars, where a channel is first identifiable. The more convergent the hollow the higher the likelihood of failure. Swales with no soil because of recent failure may present minimal hazard. The unstable portion of the hollow scales with the size of the landform. Small (narrow) landslides may occur in small narrow hollows along inner gorges. Wider landslides may be more representative in broader hollows on high relief hillslopes. Field measurements and aerial photographs indicate that the potentially unstable portion of hollows on high-relief hillslopes (see Mass Wasting Assessment) may range from 4 to 40m wide centered around the hollow axis, and the distance from ridgetops to the tops of landslide scars may range between 20 and 260m (average= 60m) and the potentially unstable portion may encompass the bottom 75% of the hollow length. Field surveys revealed landslide within hollows that ranged from 4 m (13 ft) to 12 m (40 ft) and averaged 7 m (23 ft). The potentially unstable zone of any hollow, therefore, needs to be determined in the field based on these guidelines, the size of the hollow and landform, and the signs of instability outlined above (i.e. "i - vi"); also see the guidelines in Benda, et al., 1998 (Appendix 1). The width of the zone shall be expanded by a minimum of 15 feet on either side to account for tree roots intersecting the failure plane and shall extend from the bottom to at least 75% of the entire length of the hollow. The zone shall be further extended to encompass those areas exhibiting significant signs of instability (see below).

A *moderate-hazard bedrock hollow* is defined as an unchanneled swale or valley with a slope gradient ranging from 31 to, but not including, 36 degrees downhill along the axis of the hollow. The more convergent the hollow the higher the likelihood of failure. Swales with no soil because of recent failure may present minimal hazard. Identifying the potentially unstable portion of a moderate hazard bedrock hollow should follow the same guidelines described for high hazard

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to increase the likelihood of mass wasting or contribute to the magnitude of a potenti failure. Such roads would preferably be of a temporary nature, but it is recognized tha permanent access for management activities will be necessary on some primary road systems.

If roads are constructed within these mass wasting units:

A. Stream and hollow crossing structures (e.g. bridges, culverts, fords) shall utilize keyed rock fills and be designed by a qualified forest engineer for a 100-year peakflow event. Structures shall be designed to allow passage of upslope failures. Crossings shall be surfaced with non-erodible materials such as hard rock, concrete, or asphalt.

B. All road and stream-crossing structures within inner gorges, bedrock hollows, and channel heads shall be designed, slope-staked, and field referenced by a qualified forest engineer prior to submittal of the forest practices application. In addition, all road construction shall be supervised on site by a forest engineer. Road lengths and widths within the mass wasting unit should be minimized to the extent that they remain compatible with safety requirements regarding the movement of logging trucks and yarding equipment.

C. All design drawings shall be included with the Forest Practice Application.

D. Full bench end haul construction techniques shall be utilized within these mass wasting units and in all cases on slopes greater than, or equal to, 60 percent where there is potential for sediment delivery to public resources.

E. Road drainage shall be designed to minimize water accumulation in ditches and prevent diversion between sub-drainages. This requires immediate passage (culvert, ford, or waterbar) at all drainages crossed by the road, including ephemeral channels and seeps. In addition, frequent cross drainage shall be installed at suitable locations to drain water accumulations from ditches. Suitable cross-drain locations feature a stable cut-slope and drain onto ridges or other stable slopes. Outfalls shall not be located in inner gorges unless consistent with natural drainage patterns.

F. Fine-scale secondary slope stability assessment by a qualified geotechnical specialist is required. The assessment should follow the approach and methods outlined in the most current version of the mass wasting module and should answer, at a minimum, the following questions: Will water be diverted into the MWMU? Will the hillslopes above or below the road be destabilized? Will the road fills be stable?

G. Crossing and drainage structures, as well as associated stabilization measures must, be completed before moving construction equipment from the site.

H. Construction will occur only during periods of suitable weather conditions, typically from May 15 to October 15.

I. Stream crossings located in channels that do not meet inner gorge criteria but are located upstream of adjacent inner gorge features shall meet the standards established in A through D above.

- **Reconstruction**

Reconstruction of orphaned, abandoned, or inactive roads in ARS MW-1 must meet the same standards as new construction. Road segments within ARS MW-1 originally constructed using sidecast cut and fill methods will require sidecast pullback unless otherwise authorized by the department following on-site review.

- **Existing Roads (Active and Inactive)**

Existing road segments within ARS MW-1 shall be inventoried and mapped for inclusion with the landowner's road maintenance plan. Inventory information shall identify areas of sidecast cut and fill construction, culvert locations and size, and native fills (see road maintenance plan requirements: ARS SE-1). Road maintenance shall not place any additional sidecast material within ARS MW-1.

- **Orphaned Roads**

For the purposes of these prescriptions, orphaned roads are defined as roads constructed prior to and unused for forest practice activities since the effective date of the Forest Practices Act of 1974. Landowners shall review all orphaned roads lying within the harvest unit or within 500 feet, either upslope or downslope, of any proposed timber harvest or road construction (including reconstruction) activity. These orphaned roads shall be mapped and unstable road segments identified as part of the Forest Practices Application or Notification. Concurrent with Forest Practice activity, instability problems shall be remediated, if practicable, on any orphaned road segment which is delivering or has the potential to deliver significant coarse sediment (i.e. mass failures or active gullying) to streams or to roads (proposed or existing).

- **Timber Harvest**

General

Evaluation of the hazard and impact of windthrow on inner gorge and high-hazard bedrock hollow leave areas shall consider comments and references presented in the appended project report, Evaluation of fall 1998 windthrow in slope stability leave areas at the Jones Creek and Hardscrabble harvest units (Veldhuisen, 1999). Appropriate management strategies shall be employed wherever, in the opinion of DNR, windthrow would substantially reduce the function of the leave area.

The goal of this prescription is to avoid loss of root strength within the potentially unstable feature. At times, harvest boundaries may be located along an abrupt edge demarcating an inner gorge or a high-hazard bedrock hollow. Trees located along the edge (i.e. straddling the boundary) may be contributing some lateral root strength. If there are numerous mature trees below the edge, then trees along the boundary may not be necessary to provide root strength. The removal of a portion of the trees overlapping the boundary may be allowed, where in the opinion of DNR, removal does not significantly reduce the rooting strength within the potentially unstable feature. Edge trees should not be harvested if there exists tension cracks or unvegetated landslide scars immediately below the boundary, or if there are very few trees on the unstable feature, or if the slope break is less than 4 degrees.

Inner Gorges of First and Higher Order Streams

No harvest on inner gorge slopes greater than or equal to 36 degrees (73%). Where inner gorge slopes extend beyond 100 feet slope distance from the high water mark, harvest may be allowed in the area beyond 100 feet from the high water mark if supported by a slope stability report prepared by a qualified Geotechnical Specialist. The report must assess the impact of the proposed harvest on slope stability, including rooting strength, and must be approved by the department as part of a complete application. No trees within inner gorges shall be used as tail-holds.

Minimal tree removal may be permitted without a geotechnical report to provide corridors for full-suspension skyline yarding provided that:

A. Skyline yarding would avoid otherwise necessary road construction, particularly when the only road access option would require road construction across these mass wasting units.
B. Corridor placement results in minimal cutting of trees.
C. Location of corridors shall be free of significant signs of instability.
D. Falling and yarding operations shall result in minimal soil disturbance.
E. Total corridor area shall not exceed 15% of the riparian area in the harvest unit.

High-Hazard Bedrock Hollows

Harvesting shall not occur in the potentially unstable zone of high hazard hollows (i.e.

greater than, or equal to 36 degrees (73%)) where there is a potential for delivery to waters or public capital improvements. Delineation of hollows into zones of stability must be performed by a qualified Geotechnical Specialist, Forester, or Forest Engineer. (as defined in Section 11.1). No trees within these unstable portions shall be used as tail-holds.

Moderate-Hazard Bedrock Hollows

Harvesting shall not occur in the potentially unstable zone of moderate hazard hollows (i.e. 31 to 35 degrees) where there is a potential for delivery to waters or public capital improvements unless the proposed harvest is supported by a report prepared by a qualified geotechnical specialist and approved by the department. The report must assess the proposed harvest and potential impact on slope stability, including rooting strength. Delineation of hollows into zones of stability must be performed by a qualified Geotechnical Specialist, Forester or Forest Engineer. No trees within these unstable portions shall be used as tail-holds.

Steep Slopes Outside of Inner Gorges and High-Hazard Bedrock Hollows

No harvesting on slopes greater than or equal to 36 degrees where significant signs of instability exist and landslides are predicted to reach or adversely effect water, fish, or capital improvements of the state or its political subdivisions. (See appended project report Method to Predict Landslide Runout on Non-Convergent Hillslopes by Lee Benda, Ph.D.)

Technical Rationale

The ability of landslide debris to enter stream channels depends on their runout characteristics. Although there are published runout models for channelized debris flows, there are no published models for landslide debris movement on non-channelized (planar) slopes. To circumvent this problem, a runout model was developed in the Acme watershed analysis by Dr. Lee Benda, based on the theoretical principle and empirical finding that landslide debris, which contains a relatively rigid (non-shearing)plug on the surface, will spread and thin, and deposit. A landslide runout model was developed based on this concept using published equations for shear stress of landslide debris and empirical data on runout geometry from the Acme WAU.

The landslide runout model for non-convergent hillslopes is currently being tested using data from the Oregon Dept. of Forestry. The model, however, should be used cautiously since it has not been rigorously tested. The model should be used in conjunction with other field indicators of instability and topography by experienced field practitioners. The accuracy of the model should be periodically evaluated by comparing model predictions with actual runout distances of landslides on non-convergent hillslopes.

The prescriptions are designed to prevent road failure hazards (e.g. fill failure, water concentration) during the winter storm season. Site-specific review and analysis are intended to identify which engineering techniques address and mitigate causal mechanisms.

Harvesting prescriptions are designed primarily to maintain an effective level of rooting strength and secondarily to avoid increased moisture inputs during rain-on-snow and soil disturbance from harvest activities within unstable areas.

Most landslides identified in the mass wasting module occur in bedrock hollows. The greatest number (72) of landslides occurred in high-hazard bedrock hollows (>=36°), but a relatively large number (54) also occurred in moderate-hazard bedrock hollows (31-35°). However, field study has indicated that approximately 90% of randomly selected bedrock hollows that had failed in clearcuts had slopes >=36°.

Although significantly fewer landslides (2) were recorded for planar slopes, the mass wasting assessment assigns a moderate hazard rating for 31 to 35 degree planar slopes (MWMU #3B) and a high hazard rating for greater than or equal to 36 degree planar slopes (MWMU #3A). In light of low failure frequency we have chosen to allow conventional harvesting techniques in MWMU #3B and have applied a no harvest prescription to portions of MWMU #3A with potential delivery.

Additional field assessment (See appended project report Acme WAU: Inner Gorge Topography, Landslide Inventory, and Management Practices by Lee Benda, Ph.D.) was conducted to better define landslide prone sites located within inner gorges in Chuckanut Formation. All 26 of the inventoried landslides occurred on slopes ranging greater than or equal to 40 degrees (84%). Seventy-five percent (75%) of the slides occurred in hollows with the remaining 25% located on planar slopes. On the basis of this data, prescriptions prohibit harvesting on steep inner gorge slopes of any form (>=40°).

These prescriptions are expected to reduce potential impacts to fisheries resources and water quality by reducing fine and coarse sediment inputs from mass wasting and limiting riparian disturbance (which contributes to temperature problems) caused by landslides and/or channel aggradation.

Mass wasting issues associated with existing roads will be dealt with according to road maintenance plans.